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The impact of international GHG trading regimes on penetration of new energy technologies and feasibility to implement EU Energy and Climate Package targets

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ABSTRACT

The EU's new energy and environment policy – agreed by government leaders in their Council meeting in March 2007 – established a political agenda to tackle three core energy objectives: sustainability, economic competitiveness and security of supply. A triad of specific policies addresses these challenges: first, the *20/20/20 targets* of the EU; then, the Second Strategic Energy Review of the European Commission; and finally, plans to liberalise energy markets. The European Union's '20/20/20' targets for 2020: reduce greenhouse gas emissions by 20% comparing with 1990 level (to become a 30% reduction if other major global economies join), increase the share of renewables in the final energy consumption to 20% and to achieve 20% improvement in energy efficiency compared to the level in 2020 if existing trends were to continue.

The aim of the paper is to analyse the feasibility of EU to implement 20/20/20 targets under the various international GHG trading regimes. GHG trading regimes were addressed by developing 10 energy scenarios until 2020 for EU by applying several energy modelling tools ranging from top down partial equilibrium to detailed technology based bottom up models.

Contents

1. Introduction

With the initial 2008–2012 phase of Kyoto protocol drawing to a close, UNFCCC meetings are focusing on what will come next. Though agreement has not been reached yet among countries the severe GHG emission reduction targets are expected to be imposed on developed countries. There are several widely discussed proposals for Post-Kyoto climate policy implementation mechanisms [1–4]. The emission-trading mechanism of the Kyoto Protocol should be continuously encouraged because it can promote the achievement of the targets set for countries in the most efficient way [5]. At the same time, a GHG emission trading mechanism should be devised to promote economic development in the developing world [6]. GHG emission trading mechanism could, for example, address the imbalance of emissions through a system in which industrialized countries can buy emission credits from developing countries. There are a lot of debates regarding international GHG emission trading regime in terms of quotas allocation among countries, the starting date of GHG trading and other options [5,6]. However it is clear that international GHG emission trading is the most important tool to achieve global GHG emission targets. International GHG emission trading regimes have also impact on feasibility of countries to implement their national policy goals. As there is no clear decision about post Kyoto

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GHG emissions trading mechanism the scenario approach can be applied in modelling a set of possible futures.

Scenario planning has been applied predominantly in strategic planning in management, economics, environmental decision making seeking to facilitate the identification of uncertain and uncontrollable factors that may have an impact on the consequences of decisions without turning these uncertainties into probabilities [7].

Scenarios decompose complexity by presenting several alternative plausible developments of the world. The energy policy scenarios integrating various GHG emission reduction commitments and climate change mitigation targets can explore different ways of achieving the stabilisation of key climate variables.

In December 2008 the European Parliament adopted EU Energy and Climate Package for transforming Europe gradually into a low-carbon economy and for increasing energy security. An agreement has been reached on legally binding targets, by 2020:

- to reduce GHG emissions by 20% compared to 1990,
- to establish a 20% share for renewable energy in final energy consumption and the share of biofuels up to 10% in transport fuels, and
- to achieve a 20% reduction in energy consumption by 2020 (to improve energy efficiency).

Therefore the main criteria for EU energy scenarios assessment are: GHG emission reduction, increase of the share of renewable in final energy consumption, improvement of energy efficiency and GHG mitigation policy scenarios costs.

The aim of the paper is to analyse feasibility of EU energy scenarios including various international GHG emission trading regimes to implement targets set by EU Energy and Climate Package by penetration of new energy technologies. The main tasks to achieve this target are:

- To analyse targets set by EU Energy and Climate Package and indicators relevant to these targets.
- To present 10 energy policy scenarios including various climate commitments and international GHG emission trading regimes.
- To evaluate results in terms of costs and achievement of EU Energy and Climate Package targets of 10 energy scenarios run conducted by 6 energy models ranging from top down to bottom up models presenting wide range of advanced energy technologies.
- To compare results of scenarios run conducted by specific models in terms of feasibility to achieve targets set by EU Energy and Climate Package and define the best performing scenarios and the main reasons of this performance.

2. EU Energy and Climate Package

On 10 January 2007 the Commission adopted an Energy and climate change package, calling on the Council and European Parliament to approve: an independent EU commitment to achieve a reduction of at least 20% in the emission of greenhouse gases by 2020 compared to 1990 levels and the objective of a 30% reduction by 2020, subject to the conclusion of a comprehensive international climate change agreement; a mandatory EU target of 20% renewable energy by 2020 including a 10% biofuels target. This strategy was endorsed both by the European Parliament and by EU leaders at the March 2007 European Council. The European Council invited the Commission to come forward with concrete proposals, including how efforts could be shared among Member States to achieve these targets. This package is the reply to that invitation. It comprises a set of key policy proposals that are closely interlinked. They include: (1) a proposal amending the EU Emissions Trading Directive (EU ETS); (2) a proposal relating to the sharing of efforts to meet the Community's independent greenhouse gas reduction commitment in sectors not covered by the EU emissions trading system (such as transport, buildings, services, smaller industrial installations, agriculture and waste); (3) a proposal for a Directive promoting renewable energy, to help achieve both of the above emissions targets. Other proposals that are also part of the package include a proposal for a legal framework on carbon capture and storage, a Communication on the demonstration of carbon capture and storage and new guidelines for environmental state aid.

Directive 2009/28/EC sets legally binding targets for EU member states, in order to reach the EU aggregated target of a 20% share of renewable energy by 2020 [8]. It creates cooperation mechanisms for achieving the targets in a cost effective way. Several administrative barriers and other burdens will be removed, confirming the 10% target for renewables in transport, and biofuels sustainability criteria are fixed to ensure that only those biofuels are supported that have no negative environmental impact. The directive also has implications for small-scale emitters in sectors such as transport, buildings, agriculture and waste. By 2020, emissions from these areas are to be reduced by an average of 10% compared to 2005, divided between member states according to differences in GDP per capita. National targets were set for member states, together with a linear legally binding trajectory for the period 2013–2020 with annual monitoring and compliance checks. This directive has important impact on promotion of new renewable energy technologies in EU.

Directive 2009/31/EC establishes a legal framework for the environmentally safe geological storage of carbon dioxide to contribute to the fight against climate change [9]. This directive is important in promoting advanced fossil fuel based energy technologies as carbon capture and storage.

Directive 2009/30/EC provides a set of binding targets for the emissions from the fleet of new cars which is an important tool for meeting emission targets in the non-ETS sectors [10]. The directive sets targets to ensure that emissions from the new car fleet are reduced to an average of 120 g CO_2/km. The long-term target is set to 95 g CO_2/km to be reached by 2020.

The Decision 406/2009/EC [11] lays down the minimum contribution of EU member states to meeting the GHG emission reduction commitment of the Community for the period from 2013 to 2020 for GHG emissions covered by this decision, and rules on making these contributions and for the evaluation thereof.

Therefore the main targets of EU energy policy imposed by EU Energy and Climate Package encouraging the promotion of advanced energy technologies can be addressed by selecting the appropriate sustainable energy development indicators [12]: the share of renewable energy sources in final energy consumption; increase of end-use energy efficiency comparing with reference scenario, GHG emission reduction.

3. EU energy development scenarios

10 energy policy scenarios were developed during EU project Planets by combining 2 alternatives climate targets and 5 different modes of achieving the targets [13]. The time frame from 2010 up to 2050 for 6 models (ETSAP-TIAM, DEMETER, GEMINI, TIAMEC, WITCH and PEM) completed scenarios runs however not all models were able to run all scenarios. Just TIAM and WITCH achieved all scenario runs. PEM was able to run 4 scenarios: FB-3p2; FB-3p5; SC-3p5 and VAR1-3p5.

For analysis of EU energy scenarios and they feasibility with penetration of new energy technologies to implement targets set by EU Energy and Climate Package results of 3 energy models runs will

Table 1
GHG trading commitments applied in energy scenarios.

Regions	Starting date of commitments	Commitments SC1 in 2050 w.r.t. 2005	Commitments SC2 in 2050 w.r.t. 2005
OECD	2015	−80%	−90%
Energy exporting (EEX)	2025	−50%	0%
Developing ASIA (Dev. Asia)	2025	+25%	0%
Rest of the world (ROW)	2025	+55%	+100%
World w.r.t. 2005		−28%	−26%

be analysed and indicators relevant to targets will be developed for all 10 scenarios.

WITCH – World Induced Technical Change Hybrid – is an optimal growth model of the world economy that integrates in a unified framework the sources and the consequence of climate change. A climate module links greenhouse gas (GHG) emissions produced by economic activities to their accumulation in the atmosphere and the oceans. The effect of these GHG concentrations on the global mean temperature is derived. A damage function explicitly accounts for the effects that climate change can have on the economic system. WITCH is thus an Integrated Assessment Model. The model can be called hybrid because the energy sector features a bottom-up characterisation. A broad range of different fuels and technologies can be used in the generation of energy. The energy sector endogenously accounts for technological change. Seven energy technologies based on coal, oil, gas, wind & solar, nuclear, electricity, and biofuels are included in the model. The WITCH model features a series of mitigation options in both in the power generation sector and in the other sectors. Mitigation options in the power sector include nuclear, hydroelectric, IGCC-CCS, renewables and a backstop option that can substitute nuclear. Another important mitigation option is the increase in overall energy efficiency. Improvement in energy efficiency is modelled as an endogenous process, driven by dedicated investments in energy R&D [14].

TIAM model includes a complete Climate Module. The module allows the user to set climate targets as a driver to policy scenarios. The TIAM model is driven by a set of some 42 demands for energy services in all sectors of the economy (Agriculture, Residential, Commercial, Industries, Transportation services, non energy uses). Demands are exogenously specified only for the Reference scenario, and have each a user-defined own price elasticity. Therefore, each demand will vary endogenously in alternate scenarios in response to varying energy prices. The model thus computes a partial equilibrium on world-wide energy and emissions markets that maximizes total surplus [14].

The Pan European TIMES energy system model (in short PEM) is a model of 30 countries that contains all countries of EU-27 plus Switzerland, Norway, and Iceland. The model minimizes and objective function equal to the total discounted system cost over the time horizon from 2000 to 2050. A perfect competition among different technologies and paths of energy conversion is assumed in the model. The PEM model covers at the country level, all sectors connected to energy supply and demand, for example the supply of resources, the public and industrial generation of electricity and heat, and the industry, commercial, households and transportation sectors. Both greenhouse gas emissions and also classical pollutant emissions are modelled in PEM. The generation of electricity and heat in electric power plants, combined heat and power (CHP) plants and heating plants are differentiated into public and industrial production. In the transport sector the 4 areas road transport, rail traffic, navigation and aviation are separately described. The residential sector contains eleven demand categories. The commercial sector consists of nine demand categories. The agriculture sector is described by a general process with a mix of several energy carriers as input and an aggregated demand of end use energy as output. Industry is divided into energy intensive and non intensive branches. The industrial sector is subdivided into several branches (for example iron and steel, cement, lime, etc.). An interregional electricity trade is implemented in the model, so that exports and imports of electricity according to the existing border capacities are endogenous to the model [14].

10 EU energy development scenarios were developed during EU project Planets [15,16]. They include: 2 first best scenarios, 4 second best scenarios and 4 variant scenarios. First best scenarios FB-3p2 and FB-3p5 were developed by setting alternative targets after 2050: 3.2 W/m^2 and 3.5 W/m^2. In these scenarios each target is applied with the assumption that the entire planet acts as early as 2012 in a fully competitive manner to achieve the climate target efficiently. Emission trading is allowed since 2012.

4 second best policy scenarios were developed by combating each target with one set of emission quotas or specific commitments for 4 regions. An emission quota for a given region of the world is defined as the cumulative amount of emissions that the region is entitled to, from some well defined starting date to 2050. In order to propose meaningful quotas, we divided the world into four sets of countries as follows:

- OECD countries (OECD).
- Energy Exporters (EEX): consisting of the Middle East and Russia (or some acceptable approximation of these regions, depending on model disaggregation).
- Developing Asia (DevAsia), i.e. Asia minus Middle East and minus Asian OECD countries.
- Rest of the World (ROW).

The two sets of emissions quotas (commitments) are defined in Table 1, by specifying two parameters:

- The starting date of the commitment (before that date, emissions are assumed to be those in the reference case).
- The percentage emission reduction in 2050 with respect to emissions in 2005.

For example, Table 1 tells us that for commitment SC1, OECD reductions in 2050 must reach 80% of 2005 emissions, and that these reductions start in 2015.

It is also assumed that the reductions occur linearly from start date to 2050, but in order to reflect the flexibility often mentioned in various recent pre-negotiation statements, we allow each group of countries to deviate from the annual quota, provided the cumulative quota from start date to 2050 is respected (hence, in the same example, OECD could delay or anticipate reductions defined by its quota, provided the cumulative quota is respected). The net result of these assumptions is that quotas are in fact defined as cumulative amounts of emissions for each group of countries.

The specific quotas and starting date for commitments are presented in Table 1 [16]:

- SC1-3p2 – To reach commitments indicated in Table 1 for SC1 linearly declining from business as usual from start date (Table 1) to the indicated of 2005 emissions. The target after 2050: 3.2 W/m^2.

Table 2
EU Energy and Climate Package targets and results of energy scenarios run by TIAM.

Scenarios	Primary energy intensity, kJ/EUR	The share of RES, %	GHG emissions, Mt	The cost, MEUR/year
EU 20/20/20targets	4.702 kJ/EUR	20%	4451.2 Mt	
FB-3p2	4.639	5.74	4474.62	17637.59
FB-3p5	4.719	5.17	4933.86	−2026.38
SC1-3p2	4.701	5.17	4899.88	2743.08
SC1-3p5	4.726	5.17	4925.50	433.52
SC2-3p2	4.701	5.17	4899.29	2813.26
SC2-3p5	4.726	5.17	4925.40	398.06
VAR1-3p2	4.703	5.17	4867.85	15550.78
VAR1-3p5	4.704	5.55	4890.99	9820.64
VAR2-3p2	4.691	5.17	4681.76	15550.78
VAR2-3p5	4.694	4.56	4737.93	16058.75

- SC1-3p5 – To reach commitments indicated in Table 1 for SC1 linearly declining from business as usual from start date (Table 1) to the indicated of 2005 emissions. The target after 2050: 3.5 W/m^2.
- SC2-3p2 – To reach commitments indicated in Table 1 for SC2 linearly declining from business as usual from start date (Table 1) to the indicated of 2005 emissions. The target after 2050: 3.2 W/m^2.
- SC2-3p5 – To reach commitments indicated in Table 1 for SC2 linearly declining from business as usual from start date (Table 1) to the indicated of 2005 emissions. The target after 2050: 3.5 W/m^2.

The set of 4 variant second best energy scenarios are the same as for four second best scenarios, but with a limitation on the purchasing of carbon permits between 2020 and 2050, during which period at least 80% of abatement (defined as business usual minus the allocation) has be undertaken domestically by each region, and at most 20% of the abatement can be done with international offsets (purchase of permits). The trade restriction is levied from 2050 onwards.

These 10 energy scenarios further will be assessed in terms of feasibility to implement EU Energy and Climate Packages. The four main indicators will be assessed using scenario run data of 3 different energy models: (i) the cost of scenario expressed in MEUR/year; (ii) energy intensity expressed in kJ/EUR; (iii) the share of renewable in final energy consumption expressed in percentage; (iv) greenhouse gas emissions expressed in $MtCO_2$ eq.

4. Results of EU energy scenarios runs

Just 3 models (TIAM, WICH and PEM) were able to run all scenarios. Energy scenarios were compared in terms of achievement of targets set for 2020 by EU Energy and Climate Package for energy intensity decrease by 20% comparing with doing nothing or reference scenario, GHG emission reduction by 20% comparing with year 1990 level (5564 Mt) and 20% of renewable in final energy consumption.

4.1. TIAM model results

In Table 2 the results of EU energy scenarios run up to 2020 by TIAM model are presented. The EU Energy and Climate Package targets for 2020 are also presented in Table 2 seeking to compare results achieved by various EU energy scenarios in 2020 [15].

As one can see from Table 2 just in case of FB-3p2 scenario EU GHG emission reduction and energy intensity decrease targets are achieved. The necessary share of RES in final energy consumption – 20% is not achieved in any policy scenario.

The FB-3p5 scenario has negative scenario cost obtained by TIAM model. The costs in TIAM model are expressed by the loss of total surplus (supplier's surplus plus consumer's surplus relative to the surplus of the reference scenario). The second best scenario in scenarios ranking in terms of sustainability is second best scenario with loose climate targets SC1-3p5 followed by another second best scenario with loose climate target SC2-3p5. The first best scenario with severe climate target FB-3p2 has been ranked after second best scenarios with loose because of the higher costs as the severe target requires early action and other scenarios (SC1-3p2, SC2-3p2) have quite relax quotas until 2050 and may delay their drastic GHG reduction until later. The later reductions are discounted as they occur later so the total costs of these scenarios are lower than for first best scenario with severe climate target – FB3p2. The variant policy scenarios are ranked last as they have higher cost comparing with second best policy scenarios as restrictions on GHG trading have also negative impact on implementing GHG emission quotas for OECD including EU. In general all scenarios with severe climate targets have higher costs comparing with similar loose target policy scenarios in 2020 except VAR2-3p5 comparing with VAR 2-3p2.

4.2. WITCH model results

In Table 3 the EU policy scenarios ranking results in 2020 and 2050 are presented for WITCH model. EU Energy and Climate Package targets in 2020 for energy intensity decrease, share of renewable in final energy consumption and GHG emission reduction are also presented in Table 3.

Table 3
EU Energy and Climate Package targets and results of energy scenarios run by WITCH.

	Primary energy intensity, kJ/EUR	The share of RES, %	GHG emissions, Mt	The cost, MEUR/year
EU 20/20/20targets	4.702 kJ/EUR	20%	4451.2 Mt	
FB-3p2	4.971	7.71	4549.04	211857.64
FB-3p5	5.167	4.08	5093.91	115794.22
SC1-3p2	5.275	3.58	5321.00	93914.23
SC1-3p5	5.293	3.58	5265.05	100162.67
SC2-3p2	5.273	3.58	5323.05	93568.20
SC2-3p5	5.287	3.58	5250.89	102916.21
VAR1-3p2	4.844	3.58	4519.20	119487.05
VAR1-3p5	4.778	3.22	4519.02	110217.22
VAR2-3p2	4.875	6.20	4518.00	134394.18
VAR2-3p5	4.797	3.58	4519.02	111624.40

Table 4
EU Energy and Climate Package targets and results of energy scenarios run by PEM.

	Primary energy intensity, kJ/EUR	The share of RES, %	GHG emissions, Mt	The cost, MEUR/year
EU 20/20/20 targets	4.702 kJ/EUR	20%	4451 Mt	
FB-3p2	5.138	17.25	3336.60	3381997.13
FB-3p5	5.158	16.76	3671.41	3369824.41
SC1-3p5	5.171	16.90	3665.62	3371724.61
VAR1-3p5	5.137	17.30	3421.50	3378531.18

As one can see from Table 3 just few EU sustainable energy development targets achieved by policy scenarios run provided by WITCH model. GHG emission and energy intensity reduction targets are achieved by FB-3p2 and VAR policy scenarios. The target set for renewable energy share in final energy consumption was not achieved by any policy scenario [15].

The first best energy scenario FB-3p2 demonstrates the highest share of renewable in final energy consumption, quite low GHG emissions and very high costs. Up to 2050 first best policy scenario with severe climate targets requires early action and SC and VAR scenarios have relatively easy quotas for EU until 2050 and thus delay their GHG emission reductions until late. The later reductions while costly but are significantly discounted and make total scenario costs lower of second best and variant scenarios comparing with first best scenarios. The VAR2-3p5 scenario has high share of renewable in final energy consumption but high costs.

4.3. PEM model results

Though PEM model was able to provide results just for 4 policy scenarios this model is created just for EU region therefore needs special attention in analysis of EU energy scenarios [15]. In Table 4 the main EU Energy and Climate Package targets for 2020 and results of energy scenarios run by PEM model are presented seeking to evaluate the ability of energy scenarios to implement established target.

As one can see from Table 4 all policy scenarios have achieved GHG emission reduction target however energy intensity decrease is not achieved in any policy scenario. The target established for the share of renewables in final energy consumption is almost achieved in all policy scenarios.

As one can see Table 4 the best policy scenario in 2020 is FB-3p2 though this scenario has the highest costs. However according other criteria – share of RES and energy intensity this policy scenario performs very well and according GHG emissions reduction shows the best results. Therefore higher costs comparing with other scenarios (Fb-3p5 or SC1-3p5) does not overweight the positive effect of other indicators in total assessment of scenarios. SC1-3p5 scenario demonstrates good results in energy intensity decrease, use of renewable in final energy consumption and low GHG emissions though it has the highest costs among all scenarios. The results of EU energy scenarios run by specific models in 2020 are summarized in Table 5.

As one can see from Table 5 the results of EU energy scenarios run provided by 3 energy models in 2020 are quite different. This is related with different modelling concept applied in the models. As TIAM is detailed bottom up technology model with rich set of technologies and include many options in GHG emission reduction these options provide more scope in scenario costs variations and can provide for GHG emission reduction at lower costs. The costs in TIAM model are evaluated as loss of total surplus (suppliers and consumers surplus relative to the same surplus of the reference scenario). WITCH model is top down model but enriched with key energy technologies in energy sector. The cost in WITCH model is measured as a consumption loss (change in consumption levels relative to the reference scenario) therefore the different paradigms applied in these models provide for quite different results. PEM model has the same scenario cost concept as TIAM the costs of scenario in this model are significantly higher than those provided by TIAM. This is because TIAM costs are less differentiated than in other models and model has greater depth in GHG emission abatement and this model is not yet close to using all its abatement potential then PEM was not able to solve second best and variant scenarios with severe target as has already used all potential GHG reduction measures for the similar loose climate target scenarios.

The main EU policy goals for 2020 set by EU Energy and Climate Package are: to reduce GHG emissions by 20% comparing with base year level (5.564 Mt), to achieve the share of RES – 20% in final energy consumption and to achieve 20% improvement in energy efficiency compared to the level in 2020 if existing trends were to continue or comparing with REF scenario (4.702 kJ/EUR).

These 3 goals are not together completely achieved in any policy scenario provided by WITCH, TIAM and PEM. The best results are achieved by PEM model as all scenarios demonstrate lover GHG emission than established limit. The share of RES in final energy consumption in 2020 in all models except PEM is significantly lower than EU established target. The best results in energy intensity decrease are achieved by TIAM model as this model has more options to increase energy efficiency. The best results in achieving EU Energy and Climate Package targets demonstrates FB-3p2 scenario. This energy scenario provides the lowest GHG emissions

Table 5
The results of EU energy scenarios run obtained by different models.

Scenarios	EU Energy and Climate Package targets 20/20/20								
	Primary energy intensity: 4.702 kJ/EUR			The share of RES in final energy consumption: 20%			GHG emissions: 4451.20 Mt		
	TIAM	WITCH	PEM	TIAM	WITCH	PEM	TIAM	WITCH	PEM
FB-3p2	4.639	4.971	5.138	5.74	7.71	17.25	3336.6	4549.0	3336.6
FB-3p5	4.719	5.167	5.158	5.17	4.08	16.76	3671.4	5093.9	3671.4
SC1-3p2	4.701	5.275		5.17	3.58		4900.0	5321.0	
SC1-3p5	4.726	5.293	5.171	5.17	3.58	16.90	4925.5	5265.1	3665.6
SC2-3p2	4.701	5.273		5.17	3.58		4899.3	5323.1	
SC2-3p5	4.726	5.287		5.17	3.58		4925.4	5250.9	
VAR1-3p2	4.703	4.844		5.17	3.58		4867.9	4519.2	
VAR1-3p5	4.704	4.778	5.137	5.55	3.22	17.30	4891.0	4519.0	3421.5
VAR2-3p2	4.691	4.875		5.17	6.20		4681.8	4518.0	
VAR2-3p5	4.694	4.797		4.56	3.58		4737.9	4519.0	

and the best results in energy efficiency increase by TIAM model. The PEM model indicates the best performance of FB-3p2 scenario in terms of GHG emission reduction, energy intensity decrease and the share of renewable in final energy consumption however the energy intensity target and renewable energy targets are not reached by this scenario in PEM model too.

Regarding scenario costs unfortunately they are not compatible between models as different concept were applied in models for energy scenarios costs assessments however comparing results between energy scenarios within models one can draw conclusion that first best policy scenario FB-3p5 is the cheapest option. The several studies conducted in EU also indicated problems related with meeting EU 20/20/20 targets and modelled the impact of policies on reaching targets [17–19].

5. Conclusions

1. Just 2 models from 6 completed all EU energy scenarios runs (TIAM and WITCH). EU model PEM was able to run just 4 EU energy scenarios but results of this model were also included into analysis.
2. The main EU policy goals for 2020 or targets 20/20/20 set by EU Energy and Climate Package are: to reduce GHG emissions by 20% comparing with base year level (5564 Mt), to achieve the share of RES – 20% in final energy consumption and to achieve 20% improvement in energy efficiency compared to the level in 2020 if existing trends were to continue or comparing with REF scenario (4.702 kJ/EUR).
3. The targets 20/20/20 all together were not completely achieved in any energy scenario provided by WITCH, TIAM and PEM. The best results are achieved by PEM model as all scenarios demonstrate significantly lover GHG emission than established limit. The share of RES in final energy consumption in 2020 in all models except PEM is significantly lower than EU established target. The best results in energy intensity decrease are achieved by TIAM model.
4. The best results in achieving EU Energy and Climate Package targets demonstrates FB-3p2 scenario. This scenarios has been developed taking into account loose GHG emission reduction target along with the assumption that the entire planet acts as early as 2012 in a fully cooperative manner to achieve the climate target efficiently. Efficiency also implies that emission trading is allowed as early as 2012. Therefore implementation of international GHG emission trading since 2012 can help significantly in achieving EU Energy and Climate Package targets at lower costs for EU comparing with the other GHG emission trading options in 2020.
5. TIAM model having wide range of technologies for energy efficiency increase provides best results in implementing energy intensity and GHG emission reduction target in 2020 at lowest according first best scenario FB-3p2 scenario. The implementation of EU renewable target is not being achieved by this scenario because of the limited range of renewable technologies provided by TIAM model and other restrictions imposed on penetration of advanced technologies.
6. More modelling options and more energy scenarios are necessary seeking to explore full range of options for reaching EU Energy and Climate Package targets under various international GHG emission trading regimes.

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